



System Engineering Overview

NGST Quarterly Review

17-18 February, 1998

Paul Geithner

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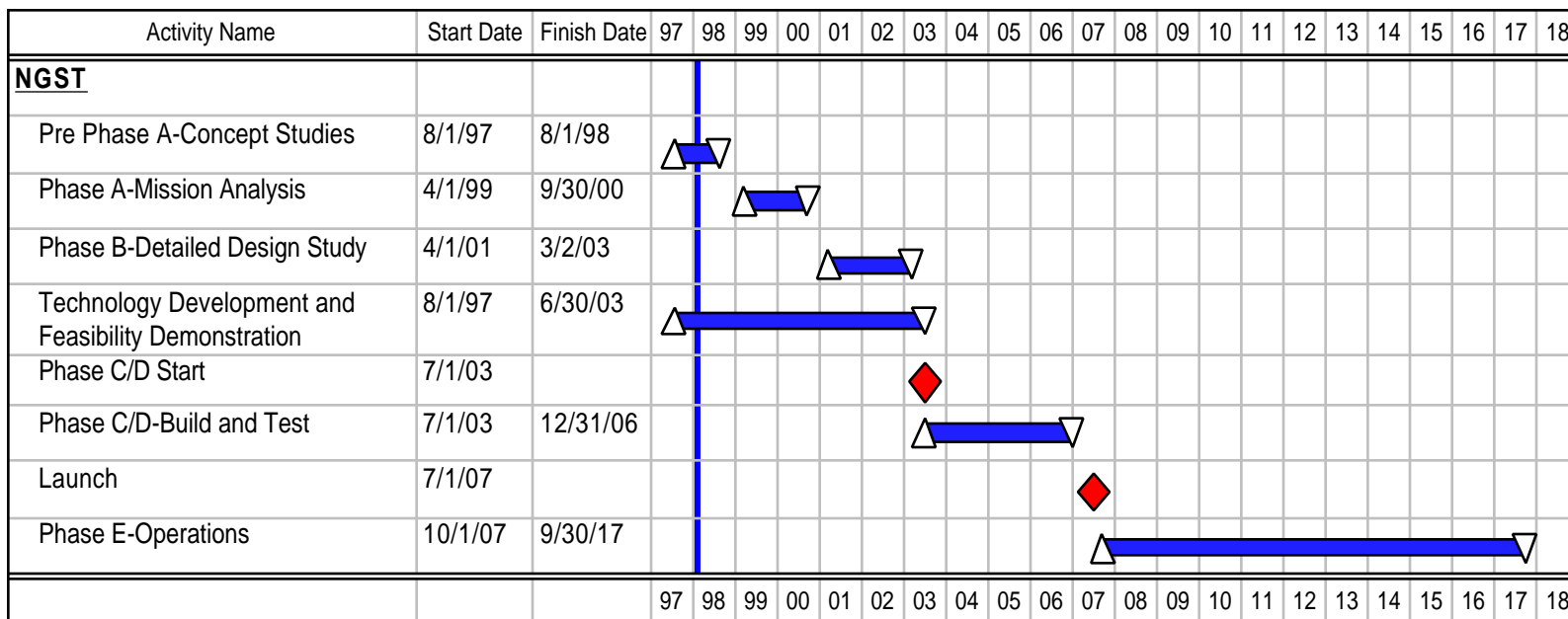


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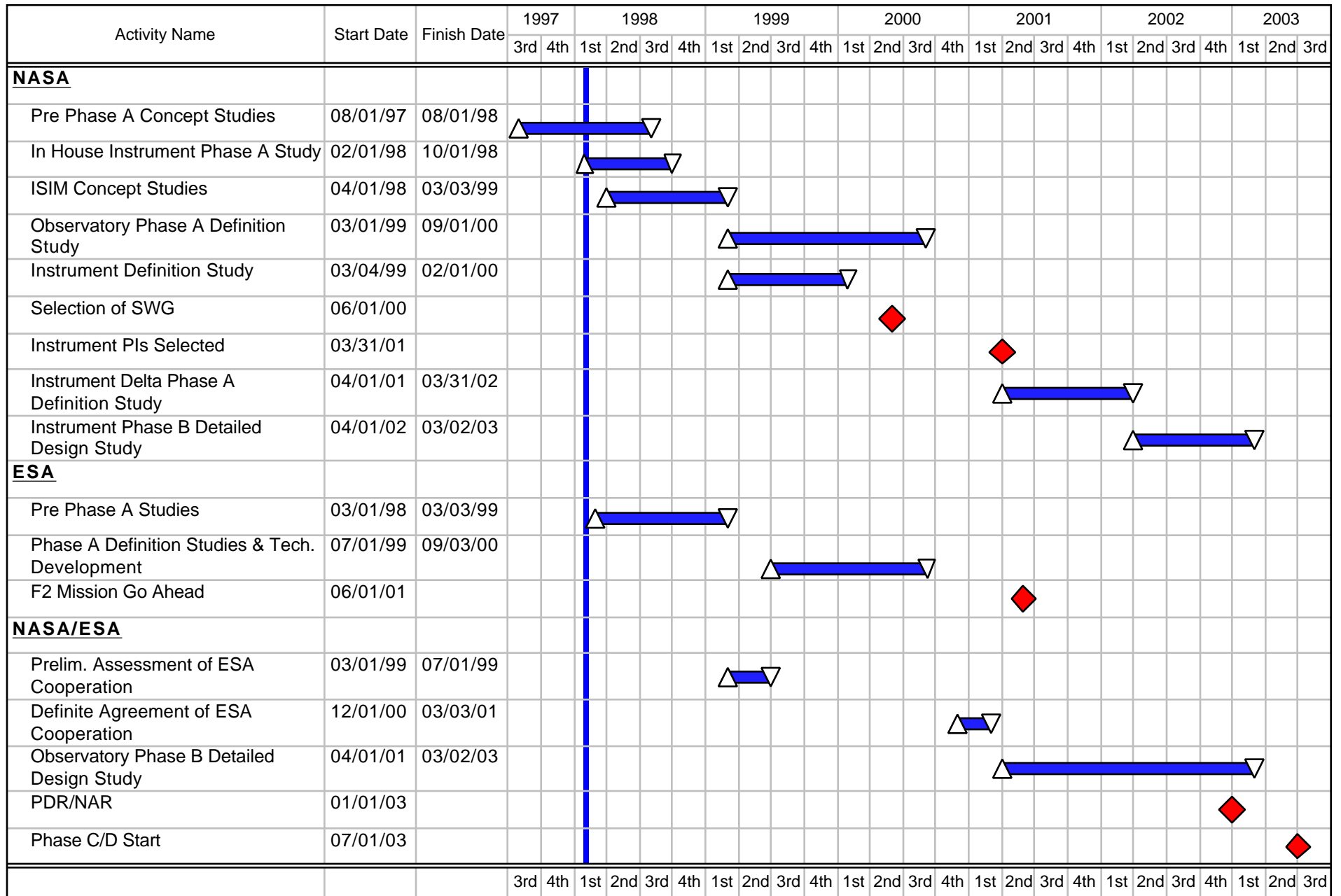
- Project Schedule
- Mission Requirements
- Notional Architecture Characteristics
- Technology Development Requirements
- Technology Development Status
- Systems Engineering “To Dos”
- Major 1998 Tasks
- 1998 Calendar of Major Events

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Top-Level Schedule



NASA/ESA Mission Formulation Schedule



Project Objective and Mission Requirements

- **Project Objective:** **Develop and Operate NGST to Accomplish the DRM in less than half the minimum mission lifetime within established resource constraints by executing a deliberate program plan**
- **Mission Requirements**
 - trade-independent
 - basis of architecture trades and design

ITEM	REQUIREMENT	GOAL
Scientific Throughput	accomplish <u>core DRM</u> in min ops lifetime	accomplish <u>entire DRM</u> in <1/2 min ops lifetime
Total Lifetime	5 years minimum	>10 years
Spectral Coverage	NIR (1-5 μ m)	Visible-MIR (0.5-30 μ m)
Field of View	wide-field (few arcmin x few arcmin)	wide-field (several arcmin x several arcmin)
Spatial Resolution	diffraction limited at 2 μ m; 0.050arcsec	diffraction limited at 0.5 μ m; 0.004arcsec
Spectral Resolution	/ up to 1000	/ up to 5000
Limiting Sensitivity	zodiacal light background limited (few nJy)	cosmic background limited (tens pJy)
Aperture	>4m diam. nearly filled (>90%) aperture	>8m diam. nearly filled (>90%) aperture
Instrument Capabilities	wide-field imaging, multi-object spectroscopy	wide-field imaging, multi-object spectroscopy, high-rejection (10^{-12}) coronagraphy
Cost Cap	develop and validate enabling technologies at TRL 6 for < \$230M ₉₆ develop system for <\$500M ₉₆ launch and operate (based on 10 year total lifetime) for <\$400M ₉₆	develop and validate enhancing and enabling technologies at TRL 6 for < \$230M ₉₆ develop system <\$500M ₉₆ launch and operate (based on 10 year total lifetime) for <\$400M ₉₆
Resource Variance	<10%	0%
Program Conduct	NPG 7120 compliant, ASO strategy compliant	NPG 7120 compliant, ASO strategy compliant

Notional Architecture Characteristics*

- **Observatory (space segment)**
 - launcher: Atlas IIAS (lift/shroud/cost equivalent)
 - environment: L2
 - operations
 - file-to-file transfers of loads, observation data
 - simple, robust safemode
 - select autonomy
 - instrumentation
 - integrated science instrument module (ISIM), passively cooled NIR/actively cooled MIR
 - NIR camera (0.6-5.3 μ m, 4x4 arcmin, res element 29 mas, Nyquist 2.3 μ m, 8kx8k InSb mosaic)
 - NIR spectrometer (0.6-5.3 μ m, R=1000, 3x3 arcmin, res element 100 mas, 4kx4k InSb mosaic)
 - MIR camera (5-30 μ m, 2x2 arcmin, res element 230 mas, Nyquist 9 μ m, 2kx2k Si:As)
 - MIR spectrometer (5-30 μ m, R=200, 2x2 arcmin, Nyquist 9 μ m, 1kx1k Si:As)
 - limiting sensitivity 4 nJy (10000s integration at 2 μ m with 20% BP for SNR=10)
 - NIR dark current < 0.02 e⁻/s, read noise <15 e⁻/s; MIR dark current < 10 e⁻/s; read noise <30 e⁻/s

Notional Architecture Characteristics (cont.)*

- **Observatory (space segment) [continued]**
 - **OTA**
 - 3-mirror astigmat
 - deployed 8m, f/1.25 PM; 90% filled aperture (7.2m equivalent)
 - deployed SM and support structure
 - position and gross figure control on PM (final correction on DM)
 - optics temperature: <70K
 - **spacecraft/physical plant**
 - configuration: warm bus, deployed sunshade, deployed truss, deployed OTA
 - mass & power: 2800 kg, 800 W
 - attitude control: RWAs with MMH reaction jets for momentum unloading and station keeping
 - pointing accuracy: 2 arcsec; allowable line-of-sight jitter: 10 milli-arcsec
 - sky coverage: full coverage over several months



Notional Architecture Characteristics (cont.)*

- **Mission Ops and Science Center (ground segment)**
 - station
 - 11m dedicated aperture (34m DSN for backup, launch, checkout, anomaly support)
 - S/X bands; 1.6 Mbps downlink, 16 kbps uplink
 - co-located comm, observatory ops, planning & scheduling, data processing and archiving
 - planning and scheduling: a few robust instrument modes and constraint checks
 - observatory ops: automated command and telemetry
 - data processing and archiving
 - 6 GB per day (compressed)
 - automated and special engineering analysis
 - science data processed and calibrated on retrieval



Technology Development Requirements

- [see hardcopy]

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Technology Development Status and Procurements

● Operability

- Strong IPT assembled
- NGST software development workshop held at GSFC

● Instrumentation

- NGST augmentation of HQ/SR NRA for NIR, MIR detector continues. Release of NRA for NGST-specific alternative NIR and MIR technology imminent
- NGST in-house Integrated Science Instrument Module (ISIM) effort kicked-off, albeit later than planned. Aim is to develop and refine Yardstick design to ØA level and flush-out system-driving cost and performance issues from the instrument perspective
- Science Instrumentation Concepts NRA proposals under evaluation. Awards for five, 10-month efforts totaling \$750k by April

● OTA

- Subscale Beryllium Mirror System Demonstrator (SBeMD) awarded to Ball/Tinsley/REOSC/Speedring/Brush-Wellman team to develop 0.50m ultra-lightweight cryogenic mirror
- NGST Mirror System Demonstrator (NMSD) hardware under construction by COI team and UofAz team
- Contract signed with IABG to fabricate carbonized silicon carbide (CSiC) mirror coupons for subsequent competitively-selected polishing contracts
- CTE testing of Be, Ni, SiC coupons ongoing at COI
- Four firms selected to develop cryogenic actuator prototypes. Awards to Xinetics, Energen, Nat'l Superconductor; award of fourth pending final round of questions



Technology Development Status and Procurements (cont)

- **Spacecraft/Physical Plant**

- Award made to ILC-Dover/L'Garde team for scale sunshade. Procurement for '00 Inflatable Sunshield in Space (ISIS) Pathfinder flight demo scheduled for this summer

- **Systems**

- Construction of Developmental Cooled Active Telescope Testbed (DCATT) continues (DCATT will be used to validate wavefront sensing and control algorithms and test alternative wavefront sensing instrumentation schemes)
- Day-long peer review of Integrated Modeling activities held at JPL in Jan to establish confidence in multi-disciplinary systems analysis methodology and tools. Panel included members from ESA, ESO, L-M, Ball, TRW, JPL, and U of Co
 - *"THE TEAM WAS SOUNDLY COMPLIMENTED BY THE PANEL FOR DEMONSTRATING A SOLID COMMAND OF THE ART OF INTEGRATED MODELING AND THE DEFTNESS BY WHICH THEY WORK ACROSS INSTITUTIONAL OR OTHER CULTURAL BOUNDARIES"*



Systems Engineering “To Dos”

	Questions	Actions	Lead (support)	Notes (schedule driver)
1	What will flight I&T be like for NGST (space <i>and</i> ground segments)? How can and should NGST <i>system</i> performance be verified before launch? How should NGST be designed for testability?	Develop an I&T plan (including verification matrix) for NGST based on the Yardstick design - ground testing implications on design and trade-offs among facilities upgrades, “cyberspace” and “proxyflight” testing, and design changes to Yardstick - contamination control plans during assy, test, handling	Geithner (Lawrence, Burg, Janice Smith, Wooldridge, Perrygo)	- HIGH Priority - first cut 4/98 (arch contractor review), final 6/98 (Qtrly, ØA RFO, SRB#2) - write monograph by 12/98
2	What might an optimal NGST look like assuming a different launch vehicle (baseline is Atlas II ARS and shroud)? When does shroud volume & dimensions cease to be the limiting constraint on space segment design? What are the driving design issues relative to booster and shroud parameters?	Perform Architecture trades vs. alternative boosters (Ariane V, EELV medium, EELV heavy, STS)	Perrygo (Purves)	- first cut 6/98 (Qtrly), final 8/98 (end of arch contractor studies)
3	Are there alternatives to hypergolics for station-keeping? Can RWAs be complemented or replaced by alternative propulsion? Can a “clean” propulsion method be used on the cold side?	Study ion beam propulsion for application to Yardstick design - compare & contrast with m (cost, schedule, testing, benefits analysis, special considerations).	Blackwood (Femiano, Zakrzewski?)	- need by 8/98
4	What are the cost relationships driving architecture design?	Further develop and refine cost models - go beyond that stated in SRB#1 package	Burg (Prince)	- HIGH Priority - relate to Mather’s SPIE cost paper - first cut 6/98 (Qtrly), final 8/98 (SRB#2) - write monograph by 12/98

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Systems Engineering “To Dos” (cont.)

5	Would decisions about NGST design/configuration, and subsequently technology investment choices, be different with a strong emphasis on NGST as a technological precursor/pathfinder for TPF?	Study NGST as TPF precursor - understand design implications - assess current technology investments for applicability to TPF - coordinate with Technology IPT	Burg (Coulter)	- coordinate with Technology IPT - involve Ball, TRW, L-M - due 5/98 (Qtrly)
6	Is a 1 AU drift-away orbit a viable alternative for the Yardstick design? How would design be different for drift-away vs. L2 orbit?	Analyze drift orbit for Yardstick - compare and contrast with L2, especially in context of orbit transfer as design drivers - determine design, deployment issues	Perrygo	- coordinate with #7 - due 5/98 (Qtrly)
7	What are the design issues associated with <i>getting to</i> L2? How should the Yardstick architecture be designed and deployed to survive transfer to L2?	Understand transfer to L2 design drivers - understand design implications - define deployment details (e.g. attitudes and degree of “unfolding” vs time and location)	Blackwood (Parrish, Powers, Wooldridge, Burg)	- coordinate with other L2 missions (MAP, Japanese IR missions) - due 5/98 (Qtrly) - write monograph by 12/98
8	What are the properties of likely NGST flight materials under relevant flight conditions (most notably, at cryogenic temperatures)	Develop a materials characterization plan, then execute it after review and approval - develop notional/generic flight materials list - research and establish known database (e.g., Young's modulus, Poisson's ratio, damping, CTE, thermal conductivity vs temperature) and identify needs for testing - pass along info to modeling, Technology IPT	Powers (Burg, Lawrence, Perrygo, Parrish, Wooldridge)	- coordinate w/ modeling #7 - Plan: first cut 3/98 (modeling #7), final 5/98 (Qtrly) - Testing/Characterization: start 7/98, complete by 7/00 (before end of ØA in 9/00)
9	What is the L2 environment really like? How does it affect design?	Describe the L2 environment - electromagnetic, charging, UV, micrometeoroids, etc. - assess effects on sunshade, OTA	Jacobson (Perrygo, Wooldridge)	- coordinate with MAP, J. Barth at LaRC - first cut 4/98 (to support #7 above and architecture contractor reviews), status 6/98 (Qtrly), final 12/98 (end of pre ØA)

Systems Engineering “To Dos” (cont.)

10	Are the current technology development performance specifications (e.g., 15 kg/m ² for PM optics) correct?	Revisit and revise as required technology development “protospecs”	Blackwood (Coulter, Bilbro, McCreight, Horner)	<ul style="list-style-type: none"> - HIGH Priority - coordinate with Technology IPT - input to Tech book - need by 8/98 (SRB#2)
11	Is CSiC (IABG’s carbonized silicon carbide technology) an attractive mirror and/or OTA structural alternative to Be and others?	Study CSiC and develop a Yardstick design version using CSiC PM segments and/or SM and/or structure <ul style="list-style-type: none"> - assess mfg process and issues - understand design implications - forecast of ØC/D cost & schedule 	Jacobson (Montgomery, Powers)	<ul style="list-style-type: none"> - support #10 above - first-cut 5/98 (Qtrly), final 8/98 (#10 above, SRB#2)
12	What is the right way to do error budgeting and express it?	Develop “parameterized” error budgets for the Yardstick <ul style="list-style-type: none"> - keep consistent with integrated modeling system-level optimization 	Burg (Redding, Geithner)	<ul style="list-style-type: none"> - covered under modeling #13 - first cut 5/98 (Qtrly), final 8/98 (SRB#2) - write monograph by 12/98
13	What does the manufacturing plan for the flight segment look like? How should NGST be designed for manufacturability?	Develop a mfg plan for the Yardstick design <ul style="list-style-type: none"> - understand facilities issues - recommend mfg technology developments to Technology IPT 	Burg (Blackwood)	<ul style="list-style-type: none"> -HIGH Priority - coordinate with #1 above - first cut 4/98 (arch contractor review), final 8/98 (SRB#2) - write monograph by 12/98
14	Are the mission-level requirements correct? How would they flowdown as requirements and specification for the Yardstick design?	Revise mission requirements and Yardstick-based spec flowdown <ul style="list-style-type: none"> - get input from ASWG, activities listed above 	Geithner (Blackwood, Bely, Burg)	<ul style="list-style-type: none"> - HIGH Priority - first cut at current flowdown 4/98 (arch contractor review), revision 8/98 (SRB#2), update 1/99 (following ASWG, other input) -write monograph by 1/99



Key Activities for CY 98

● Administration

- engineer, define, and establish system acquisition strategy
- finish Cost & Process IPT activities
- develop updated ISO-9000 compatible project plan
- establish ESA/NASA, CSA/NASA, NRO a/o DoD/NASA working relationships
- reassess and justify flight experiments
- finish contractor pre-ØA architecture studies
- produce ØA draft RFO in Sep (award early CY 99)
- start technology state-of-art and roadmap book (following NMSD ambient tests in Dec)
- define interaction strategy and plan for the Decadal review

● Demonstration and Validation

- complete assy of, get “first light” through DCATT
- pursue alternative NIR, MIR focal plane options, testbedding facilities
- test NMSD mirrors under ambient conditions
- contract for begin test article construction of non-glass mirror alternatives (CSiC, Be)
- build developmental precursor flight cryogenic actuators
- develop subscale sunshade, begin procurement of ISIS flight hardware
- fly reverse-Brayton cooler (HOST test mission for HST SM-3)

Key Activities for CY 98 (cont)

● Study and Analysis

- refine DRM and revise mission requirements
- conduct and document first-order operability trades
- define top-priority advances in flight software development methods
- continue development of adaptive scheduler and scientist's expert assistant prototypes
- understand science instrumentation issues, trades, interface definition
- refine cost models and cost estimating relationships (CERs)
- define notional manufacturing, I&T plans
- refine integrated network schedule
- define notional specification flowdown, parametrized error budget for "Yardstick" design
- update and revise technology development requirements
- understand orbit transfer and environmental design issues
- examine alternative architectures based on different booster assumptions
- characterize cryogenic material properties
- execute higher fidelity modeling of "Yardstick"
- receive report of parallel ESA studies
- revisit and update mission requirements



Major Upcoming Events for 1998

- **Mar**
 - NRO/AS&T Senior Mgt Group(SMG), 9th
 - SPIE conference in Kona, 20-28th
- **Apr**
 - NMSD CDRs, 14-17th
 - Architecture contractor interim reviews, 21-22nd
 - NASA/ESA #3 at GSFC, 24th
 - SBeMD RR (TBD)
- **May**
 - Cryo Actuator PDRs (TBD)
- **Jun**
 - NGST Tech Challenge #2 in Oxnard, 3-5th
 - NGST Workshop in Liege, 15-18th
 - ISIS PDR (TBD)
- **Jul**
 - NGST quarterly (TBD)
- **Aug**
 - cryo actuator CDRs (TBD)
- **Sep**
 - SRB#2, 15-17th
 - draft ØA RFO on www (TBD)
- **Oct**
 - Science PNAR, 1-2nd
 - NGST quarterly (TBD)
- **Nov**
 - BFZ
- **Dec**
 - NMSD ambient performance demos (TBD)